NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER SAN DIEGO, CALIFORNIA 92152

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AN APPROACH FOR MEASURING BENEFIT AND COST IN MANAGEMENT AND INFORMATION SYSTEMS

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A technique is developed for assessing benefit and, to a more limited degree, cost in order to permit meaningful cost-benefit analysis of management and information systems. The technique is most immediately a response to requirements in analyzing a large and complex manpower planning and programming system. It is more generally a response to an apparent gap in existing cost benefit methodology in regard to obtaining useful performance measures in managerial information systems.

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A model with three prime determinants of benefits is postulated: Potential contribution, Received value, and Utilized value. Other candidate factors are also considered, notably feedback. A methodology for costing inputs and outputs is also developed as an important complement to the benefit measures. Analysis results are presented for preliminary data gathered via a questionnaire. Alternative models for considering the measures are discussed. A plan for detailed analysis of the model using extensive data now being collected, in addition to proposed laboratory experimentation, is presented.

FOREWORD

The advanced development covered in this report comes under ADO P43-07X.01, Manpower Requirements and Resources Control System (MARRCS). The overall objective of MARRCS is the improvement of efficiency and effectiveness in Navy Manpower Planning and Utilization through scientific application of selected technologies and the development of new technologies as appropriate. Phase I MARRCS is concerned with an analysis of the existing manpower planning and programming processes in the Navy sufficient to establish a basis for improving current systems management and for developing future systems.

The work accomplished in this report was under the direction of Mr. Elmer S. Hutchins, Jr., the Phase I MARRCS Project Director. Overall guidance and direction was provided by Dr. Richard C. Sorenson, Associate Director for Management Systems Research and Development.

The assistance of the MARRCS project staff in the collection of the data used in this study is greatly appreciated. In particular, DP2 Gary Godtland, USN, was especially helpful in managing the data and computations. Dr. Raymond E. Willis, University of Minnesota, was a valuable source of consultation in the development of the initial planning for Phase I.

J. J. CLARKIN
Commanding Officer

SUMMARY

Objective

Develop a technique for assessing benefit and cost in the analysis of management and information systems.

Results

1. A literature search revealed that existing techniques did not meet the objectives of MARRCS (see FOREWORD).

2. A model was developed to identify relative benefit and its factors. The conceptual building block was a "communication" put out by a producer and input to one or more consumers. Three prime determinants of benefit were postulated – potential contribution, received value, and utilized value. A data collection instrument was developed as part of the larger MARRCS data collection device, and a sample of data was statistically analyzed to determine to what extent the postulated factors explained overall benefit of information as perceived by participants in the existing manpower planning system. The factors were determined to be meaningful in conceptualizing and measuring benefit. Potential contribution was revealed as the strongest of the three in the data used. Regression analysis was also performed using a dichotomization by "producer only" and "consumer only" data. The basic model tended to function best with "producer only" data.

3. A methodology was developed for costing inputs and outputs. Representative cost parameters were formulated for four labor categories: officer, enlisted, civilian professional, and civilian clerical.

Recommendation

Refine the technique developed in this study and apply it in the analysis of managerial systems.

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INTRODUCTION

Problem

The measurement of benefit and cost lies at the heart of the assessment of decisions and decision making systems. The literature supporting several disciplines, most notably economics and operations research, abounds with techniques for analyzing benefits and costs once they have been measured (e.g., references 6, 32). In the case of hardware systems, the measurement of benefit, at least in a performance sense, is quite direct. For example, an aircraft design is considered in terms of its ability to meet certain predetermined performance specifications. The benefit appertaining to a given aircraft design alternative is the extent to which the performance specifications are met by that design. That is not to say that obtaining the performance measures is a simple matter as attested to by the sophistication of prototypes, test sites, monitoring instrumentation and the like. The measurement of costs for hardware systems again appears to be quite direct, although perhaps less so after recent experiences with hardware systems under development (i.e., cost overruns).

Turning to the analysis of benefit and cost in the public sector, one must deal with social welfare and social cost, which are certainly more nebulous variables than those one deals with in hardware systems. Nonetheless, a number of approaches have been documented for this type of problem (reference 33). In reviewing these approaches, one can begin to see, however, that the difficulty of measuring at least benefit, if not cost, severely restricts the sensitivity and sophistication of the techniques proferred. In fact, a general observation that can be made concerning existing cost-benefit methodologies is that their ability to produce results which can actually be applied to real systems varies directly with the extent to which cost and benefit can be measured in dollars or other definitive unit terms. The many important kinds of problems whose consequences cannot be so characterized are usually either not dealt with by the discipline or are so diluted by simplifying assumptions that resulting solution techniques have little practical utility (reference 50).

The analysis of management and information systems, unfortunately, is one of those areas in which it has not been possible to extensively apply cost-benefit techniques within a systems analysis framework for want of appropriate measures. No one has yet been able to specify a solid strategy for determining the marginal revenue product of staff members or their information products (reference 33). Since the Phase I systems analysis effort required that the Navy's existing manpower planning system be analyzed within a cost-benefit framework, it became essential to develop an effective benefit measurement approach.

Objective

The MARRCS Phase I effort will result in identification, description, and analysis of the decision making and information processing that occur in the existing Navy manpower planning system. The objective of the approach presented in this report is to support the

Phase I effort, as well as contribute to existing methodology in the systems analysis area. In so doing, the report provides an effective means of assessing benefits and costs in management and information systems for which it has not been possible to make direct conventional measurements of performance.

By far, the primary focus of the approach is on measuring benefit, rather than cost. Obtaining cost measures for the kind of systems towards which the approach is aimed has thus far been more a function of persistence and data collection resourcefulness than of methodological innovation. Nevertheless, the costing technique serves as an indispensable complement to the approach described for measuring benefit. Once benefit and cost measures have been obtained, it may be possible to develop innovative models for information cost analysis.

The cost and benefit indices obtained through this approach are being used to identify development opportunities and priorities and to permit comparisons between present and proposed systems for manpower planning in terms of possible increases in effectiveness. Scales that are based on the benefit model presented in this report make up part of a larger instrument that is the primary vehicle for MARRCS Phase I data collection. That instrument, the Manpower/Personnel Planning Questionnaire, is included in this report as Appendix A.

Background

The manpower planning system under analysis in Phase I is a large-scale decision-making organization. It may be viewed as a network of elements performing decision-making and information-processing functions (nodes) that are connected by their incoming and outgoing communications (arcs). Each node in the system has certain information requirements (inputs) and in turn produces information or decisions (outputs) to meet the needs of other nodes in the system. These nodes may utilize a wide variety of broadly recognized decision making techniques. For example, it may be the function of a given node to determine which of a variety of skill categories will perform most effectively in a certain kind of position. More commonly, a node will be actively involved, not in making a decision per se, but in producing or processing information that will be used for decision making or control at higher levels in the organization.

In the Phase I study we are concerned with how the present management system determines the manpower requirements of the operating forces and their support, and provides for the fulfillment of those requirements in the face of fiscal and personnel inventory constraints. The most obvious and direct measure of the performance of such a system would involve an ability to gauge the contribution to the effectiveness of the operating system[1] that is directly attributable to its manpower resource array. As a basis for development of the management system, it is also necessary to be able to attribute various factors of the system's impact on operations to both specific *elements* of the management system and specific *functions* performed.

Thus, at least three kinds of measures must be examined to reveal their respective difficulties and advantages. First, the idea of directly measuring manpower performance in the operational system and using this as an index of the manpower management system's

[1]This term is used to refer collectively to the operating forces and their support.

effectiveness must be discounted. It would be impossible to sift, from the manpower performance variable, the effects of decisions made by the manpower management system as opposed to the effects of equipment, operating conditions, leadership, personnel assignment, etc.[2] Therefore, we are forced to evaluate the outputs of the management system in their abstract form (i.e., sets of manpower requirements). We thus seek to evaluate perceptions of elements in the operating system that receive the management system's product.

Figure 1 provides a visual aid to this explanation. The triangle at the right of the chart depicts the operational system. Points A and A^1 indicate where direct measures of manpower effectiveness would be drawn if that were possible. Points B through G indicate where measures are being obtained in the Phase I study. The manpower management system is portrayed as a prism composed of the basic activities of alternative generation and selection. The former activity tends to expand the information under consideration through information collection and processing (generation of alternatives), while the latter tends to eliminate or converge information through filtering and decision making (selection among alternatives). The breakpoint between these two activities is, of course, a conceptual abstraction, but it is useful for differentiating and geometrically locating the functions performed within the system with time and space coordinates.

A second kind of measure exists at point B, the interface between the manpower management system and the manpower "brokers" residing in the operational system. This is the perceived effectiveness associated with the set of requirements produced by the management system. When we obtain this measure from respondents residing in the operational system, we must account for certain biases. For example, they are likely to view the requirements of the operational system – the crying need for billets – with less consideration for personnel inventory and fiscal constraints than planners in the manpower management system. Requirements decisions may be viewed by these respondents as good or bad solely on the basis of the number of billets approved.

The majority of the data being collected is related to a third kind of measure at points C and D in Figure 1 – that is, it lies within the manpower management system itself. Since the *elements* of that system and the *functions* performed therein are identified within C and D, we stand to uncover the best opportunities for system development at these points. The approach seeks to identify: what information and functions must be produced, how well these needs are currently being filled, what determines benefit in this system, what activities or data are perceived to have low (or high) benefit, what costs are being incurred to operate the system, and so on.

The validity of using perceptual data concerning benefits need not be defended solely on the basis of its being the only data available. In spite of advancements toward automation, most management systems remain "people systems". It may be argued that, regardless of the "objective" value of a piece of information or a decision outcome, it is the user's perception of its value that will determine its utilization and hence its ultimate impact on the system's performance. Following this line of reasoning, the major drawback of using perceptual as opposed to performance data to evaluate benefit is specificity, not validity. To know that a given input is viewed by a decision maker as "good only some of the time"

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[2]This might be possible in a limited way via a contrived laboratory experiment. However, such an approach is neither feasible nor desirable in the Phase I study.

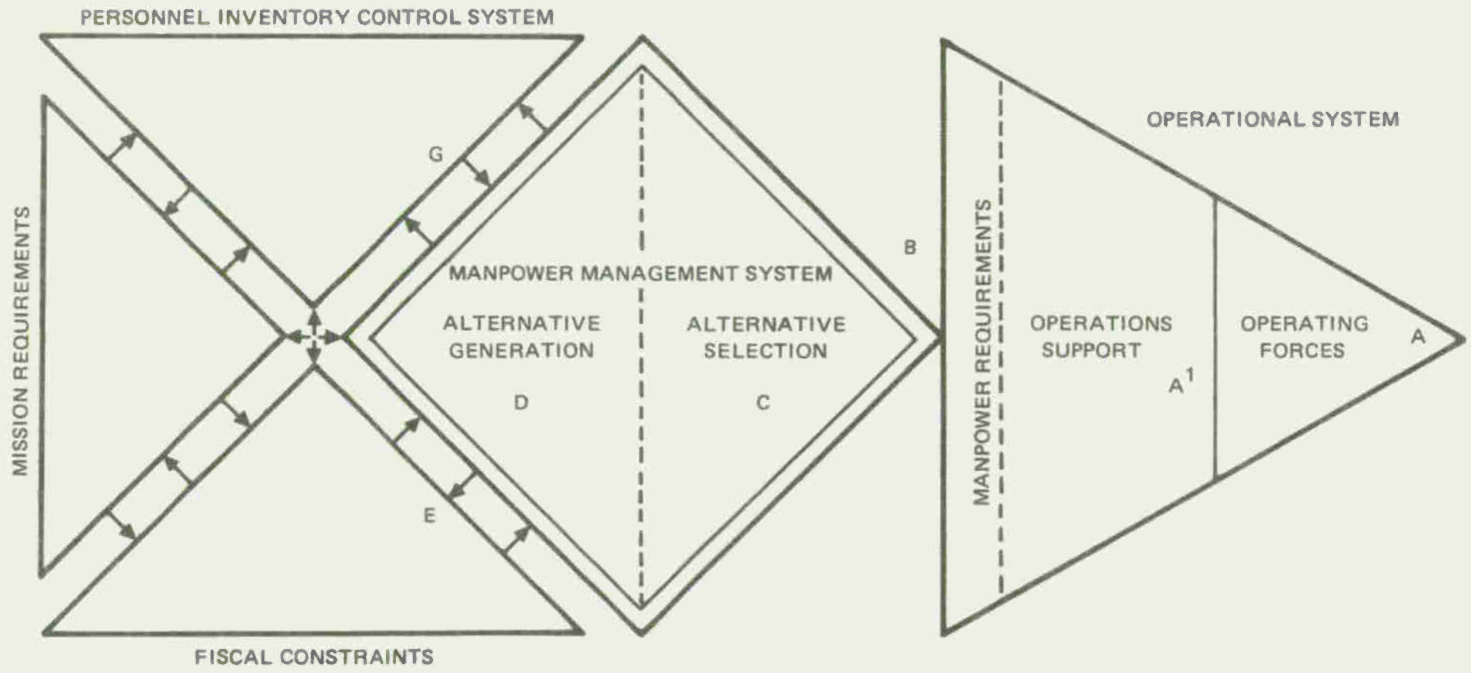

Figure 1. Location of system measures.

(i.e., a linguistic variable) alone does little in the way of giving the system developer a lead towards improvement.[3]

The approach presented here attempts to show how the major *factors* of benefit can be identified and assessed, thereby permitting more specificity to be attached to perceptual data. It is an approach for obtaining and relating data that will enable one to be specific not only about a particular system element but also about what determines the benefit of information and decisions in the system as a whole. It seeks to identify (in the context of Appendix A) the differential effects of the various aspects of information processing and decision making, with respect to (1) function of the system element, (2) type of communication, and (3) organizational context, as well as other more technical factors (e.g., cost, periodicity, processing or decision making technology).

Thus, the approach described below, in order to obtain benefit and cost measures that will facilitate system development, focuses upon the exchange of information within the management system and across its boundaries with other support and operational systems, and makes use of perceptual evaluations of the benefit of that information.

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[3]Some recent work (e.g., Zadeh; reference 78) has been directed at developing a conceptual framework for dealing with systems that are too complex or ill-defined to permit precise quantitative analysis. This work includes the definition of "fuzzy" variables (linguistic variables), "fuzzy" sets, "fuzzy" algorithms, etc.

APPROACH

Benefit Measurement – An Overview

. . . it is the job of the scientist to discover appropriate measures. . . . the wartime origins of operational research stress the importance of discovering how to create measures which have no conceptual existence, never mind usable measuring rods, before. . . . people may not have believed that a measure could be devised, but they would not necessarily have said that what had to be measured was not at all susceptible to measurement. Yet cases of this kind do occur. It has already been pointed out that the history of science discloses many examples of actual persecution based on the belief that certain things were strictly incommensurable.

Stafford Beer
Decision and Control (reference 7)

Difficulties in the measurement of performance benefit have historically been an encumberment to the analysis of management systems in the economic, behavioral, and operations research disciplines. Economists, especially those working in the field of microeconomics, rely upon a pricing mechanism for the designation of relative value of alternative patterns of production or consumption. They employ econometric techniques to generate supply and demand curves from time-series or cross-section data. These curves then enable prediction of market response to changes in price or quantity of the particular good or service under study. (All of this construction is theoretically bulwarked by indifference curve analysis, which is posited on the assumption that individuals can accurately, and rationally, express and compare states of relative satisfaction, or utility, based upon offers of different collections of goods and services.) Because of this reliance upon the price system to reflect relative values of alternative products, the microeconomics approach is not readily applicable to this problem area. There is no established marketplace for the exchange of the information resources and products intrinsic to management systems. In addition, an unambiguous pricing structure cannot be assembled from the recorded description of such a system.

The economist, then, would be more comfortable in the application of his methods if there existed a market arrangement within which well-specified packets of information could be bought and sold by process participants. Such an environment would enable ready definition of the worth of any intermediate or final information product, determined by the amount which consumers would be willing to pay to procure it. Unfortunately, such a milieu does not exist. Further, the management mechanism does not lend itself to the abstraction necessary to allow analysis within such a framework.

The field of operations research has produced highly sophisticated mathematical decision tools. Virtually all these tools depend upon the capability for quite specific definition of constraint features, production, and objective functions. The coefficients in the resulting equations reflect the requirement that alternatives be measurable in terms of either dollars or physical units. The problem with the dollar yardstick was described above. There is a similar difficulty involved with attempting to define a unit size for "physical" measurement of information packets. Certainly, benefits could not be reflected in word or paragraph counts in a meaningful way – nor in counts of transmitted concepts, thoughts, ideas, etc. Since limitations restrict one's capability to specify adequately the components of the operations research (OR) models, they are unsuitable for application here.

Therefore, neither the models developed in the economics field nor those characteristically employed by operations researchers can be relied upon in this kind of problem because of measurement constraints. On the other hand, the behavioral scientist has been forced to focus more on the problems of measuring satisfaction or utility in the derivation and application of his models. The theorization and explanation of satisfaction/motivation and its effects have been actively pursued by behavioral scientists for many years. Unfortunately for all parties concerned, there has not been a great deal of interaction and assimilation between economics or operations research and the behavioral sciences in the benefit measurement area.[4] This may be partly due to a tendency for such terms as utility, satisfaction, motivation, performance, benefit, and payoff to be provincialized and falsely differentiated among the three disciplines. While technical differences do, of course, exist, these terms are essentially all measures of value. The economist uses the terms utility and satisfaction to describe, for instance, the value a consumer derives from a particular kind of consumption. Psychologists, at least those adhering to the cognitive orientation, use measures of satisfaction and motivation to predict performance, the nexus being that people act in accordance with the utility they perceive to be associated with the performance. OR analysts attempt to denominate benefits or payoffs associated with different outcomes. These are subsequently weighed against the costs of achieving them. Implications for action exist whenever there is a net benefit or cost.

The three cases above all concern the following decisions based on value: (1) How much does the consumer value the consumption of one more unit? (2) What value set forms the basis of behavior? and (3) What value will imply the selection of one alternative or another? These decisions are basically the same. They are approached differently depending upon whether one is interested in predicting (ex ante) or assessing (ex post) results and whether there are limitations upon measuring one or the other.

The conditions associated with the direct measurement of the impact of the management system on the operational system have been specified in the preceding section. These conditions similarly apply to the measurement of effectiveness within and among the various elements of the management system itself. In this situation, one becomes constrained to evaluating the information products that elements within the management system provide to one another, rather than the ultimate impact of such products upon actual operations. To put it another way, we are measuring perceived rather than demonstrated effectiveness.

Considering this, the following approach borrows liberally from the behavioral sector. Subjective measures of benefit are used; however, in the manner of current behavioral orientation[5] benefit is approached via several factors and a theoretical construct that relates them.

The Navy manpower management system is conceptualized as a network whose nodes are the various information processing and decision making groups in the system and whose arcs are the communications (e.g., information, decisions, guidance, etc.) that flow through the system. The system is bounded above by the multiyear JCS objectives (JSOP-II) and below by the requirements of the operational system – those organizations to whom

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[4] A notable exception to this is the work of Katona at the Survey Research Center, University of Michigan which tends to bridge the psychological, economic, and sociological areas.

[5] There is a direct relationship between the approach developed here and the construct of expectancy theory (e.g., Vroom, reference 72) and its current extensions (e.g., Graen, reference 28).

manpower is allocated in the form of billets. The microdynamics of the network are characterized by producer-consumer interfaces through which the various communications relevant to manpower planning are channeled. A given node (processing unit) can be an information producer, consumer, or both.

A decision maker in a resource allocation setting, such as a manpower planning system may be thought of as dealing with the following model.

Let X be the set of decision variables and Y the environmental description. If π is a payoff measure based on perceived values, then the decision maker tries to conceptualize a payoff function $\pi = \pi (X, Y)$ and choose X so as to optimize π. Much of this process is clearly subjective and informal. Yet, by accepting the existence of such a model, one can better identify the kinds of information that are relevant to this process as well as the attributes of such information that must contribute to the pursuit of decision optimization.

The model implied above can of course be stated more formally, for example, as a LaGrangian with a utility function $U = U (X_1, X_2 \ldots X_n; Y)$, cost $C = \Sigma Xi$ (budget constraints) and various allocation constraints. As a practical matter, the appropriate expressions of such a function are known at best imperfectly. However, our assumption is that participants in the management system are trying to solve this or analogous problems, or are supplying and maintaining information in support of such efforts.

From this problem setting we can deduce that certain kinds of content should be evidenced by the communications that flow through the system. The following typology (Table 1) was used in this study as a means for classifying information for application of effectiveness measures. It also serves to validate the system concept presented above.

TABLE 1

TYPOLOGY OF INFORMATION CONTENT IN THE MANPOWER MANAGEMENT SYSTEM

1.	Procedural specifications/action statements (approvals, denials)
2.	Structural information (definition of problem elements to be considered)
3.	Quantitative information (numerical specification of the coefficients of constraints, production, or objective functions)
4.	Documentation (description of processing strategy)
5.	Environmental forecasts (specification of scenarios, projection of environmental variables; quantification of the risk element of decision making)
6.	Performance evaluation (feedback, sanctions)
7.	Specification of resources available to management itself (time, manpower, equipment, funding)

The Model – PRU

The approach formulated to assess benefit in the kind of system described above postulates three benefit factors:

- Potential Contribution (P) – This is a value attached to the information on the basis of some predetermined set of specifications that the information should meet.
- Received Value (R) – This is the portion of potential contribution that is normally received by users of the information.
- Utilization Value (U) – This is the portion of received value that users are normally able to actually apply in performing their functions.

The model relating these three factors is multiplicative as follows:

(1)	Realized Value (Benefit) (a scalar)	=	Potential Contribution (a scalar)	X	Received Value (a percent)	X Utilization Value (a percent)

The three benefit factors and their interrelationships are described in detail in paragraphs 1 through 5 below. The scales used to collect data on the three factors are presented in Part IX of Appendix A (pages 52 through 53). A basic paradigm of the approach is a communication linking its producer with its consumer(s). The communication may contain information of the types delineated in Table 1. Furthermore, the information may be in its raw descriptive state, its processed or semiprocessed state; or its fully resolved prescriptive state (a decision result). We are first concerned with the perspective of the consumer. By all management information theory principles, the communication should be a response to some need of the consumer. It should have some value that can be stated in potential terms.

1. Potential Contribution

This first factor of benefit, is termed potential contribution (P). P is a value that reflects the ideal contribution of the communication. It may best be understood as a negotiated value. For example, before any exchange of information has taken place, the producer and consumer may agree as to the nature of the communication (e.g., content, scope, level of detail, accuracy, frequency). The consumer views this ideal communication as having some potential impact upon the function he is to perform. This visualized impact is the potential contribution of the communication. This value is conceptually distinct from what is *actually* produced, received, and utilized. P is most readily tied to the objective of the communication. While there may be no formally stated objective for the communication nor a clearly negotiated understanding of what the communication is to contain, there should always be some basis upon which the producer produces and the consumer consumes.

The scales developed to collect data on the P factor used integers ranging from 0 (no contribution) to 4 (very high contribution). The points on this scale are not necessarily a reflection of norms or standards. Since a communication can be multidimensional, one must be careful not to interpret a "no contribution" response as an indictment against the information that the communication contains.

a. Broadcast and Content Dimensions

A communication has both *broadcast* and *content* dimensions. The broadcast dimension refers, for instance, to the transmission of a given information module to a set of

consumers. Not all consumers will have equal need for the information. The information may be critical to the function of one consumer (A) and only of passing interest to another (B). Moreover, transmission to B may only be cost justifiable because of A's need for the information. In addition, secondary consumers may not have influenced negotiated specifications for the information and thus will receive a "ready made" product as opposed to a tailor-made one. Fixed cost for producing management information, as can be seen in the cost section of this report, is high, whereas the apparent variable cost associated with sending the information to additional consumers is relatively low.

Another consideration in the broadcast dimension is that contribution as measured on the scale is relative to the criticality or importance of the consumer to the system as a whole. Thus, if one is to compare potential contribution across consumers, it must be understood that, though a given communication may yield low contribution to consumer B and high contribution to consumer A, its ultimate impact on overall system effectiveness may be greater through B than A, given that the former has the more critical system function. The effects of the broadcast considerations may be viewed as follows:

$$(2)\quad \frac{\text{Potential Contribution} \times \text{System Impact of Consumer's function (weight)}}{\text{Cost of Transmission}} = \text{Index of Potential Contribution to System Effectiveness}$$

Equation (2) shows the difference between the concept of potential contribution as it is applied to the single producer-consumer paradigm, and as it is applied to overall system effectiveness. The utility of the former concept in system development is at least partially independent of the latter usage. It is of value for a system developer to know that a particular communication is viewed as having a certain contribution by a given consumer. From this sort of data may be developed improvements in various producer/consumer interfaces through the clarification, augmentation, or elimination of current communications. However, in many cases, the larger bases for such developmental actions may not be clear without considering the broadcast dimension of equation (2).

The *content* dimension refers to the possibility that (1) several uses will be made of the information contained in a given communication and (2) a given communication will contain several kinds of information, each having a particular use. For example, the manpower planning system is part of a larger system that manages the Navy. A piece of information used in manpower planning may have additional, largely independent contributions to other management functions (e.g., finance, logistics). Furthermore, a communication of considerable magnitude (e.g., a fiscal guidance memorandum) may contain information relevant to both manpower planning and hardware acquisition.

Of first concern, then, is the context of the respondent's perception of potential contribution. It must be determined whether (1) he is referring to only the manpower-related segment of the communication or to the communication in general, and (2) he is reporting his perception based only on the use he makes of the information in manpower planning, or on his total potential use for the information, manpower planning and other functions included.

b. Provisions for Dealing with Broadcast and Content Dimensions

The benefit/cost approach developed provides for the considerations identified above. However, since the model is multiplicative, these considerations are factored into the product of the three benefit variables as opposed to being directly applied to potential contributions. As a means of accounting for variable consumer impact on total system effectiveness, it is possible to apply weights to the benefit computation result (or to any of its factors). These weights may be based on (1) management perceptions, (2) the results of a system analysis, (3) hypotheses about impact in the system, or (4) proposed changes to the system structure. (Of course, other bases for weighting could be developed if necessary.)

The cost of transmission consideration is explained in depth in the cost section of this report. It is possible to consider both "shared" and "total" cost in cases of multiple consumers. In addition, it can be helpful to distinguish primary and secondary consumers of communications, thus perhaps opening the way to a more direct cost allocation scheme.

The content dimension problem was addressed in the data collection process by using an introduction that carefully specified the kind of information being considered in the analysis (i.e., manpower planning information). Additionally, respondents were asked to indicate whether the communications referred to were also used for purposes other than manpower planning. In addition to its importance in interpreting the benefit ratings, the usage question obviously has direct pertinence to the question of whether a given communication link should be maintained. Even if the benefit of a multiple-use communication for manpower planning purposes was zero, a recommendation could not be made for its discontinuance until its nonmanpower usage was also properly evaluated.

2. Received Value

Once the concept of potential contribution has been established, it is possible to examine the portion of that potential that ordinarily is received by the information consumer. There are a variety of reasons why less than the total potential contribution may be received (or produced). The communication producer, an information processor, or a decision maker, as we have thus far defined him, is constrained by the quantity and quality of *resources* at his disposal. As pointed out above, products in addition to the subject communication must also be produced. It is thus reasonable to adopt the conventional economic assumption of limited resources and unlimited demand. Because of this system characteristic, it may be an optimal strategy for the communication producer to devote less than the total amount of resource necessary to realize the total potential contribution of the communication. It may also be the case that, regardless of other demands on his resources, the producer may simply not have the resources necessary to meet the potential.

Time presents a similar constraint. It may be that, beyond a certain point, the addition of more resources to the communication production process may have no effect on achieving the potential value unless more time is allotted. This sort of constraint is strongly suggested by the likelihood that delivery of inputs necessary for communication production will be out of the producer's control. The producer is usually highly dependent on his suppliers, just as his consumers are highly dependent on him.

Received value can be thought of in both a relative and an absolute sense. It is relative when applied to the potential contribution value – that is, as a percentage of that potential value:

(3) 3.0 Potential Contribution X .75 Portion Received = 2.25 Received Value

It also has meaning in terms of "portion received" expressed as a percent. Depending upon the number of observations collected on this percent, it is possible to characterize the producer's ability to produce the communication. Accordingly, if we are looking at a group of producers that share common characteristics (e.g., residing in the same subsystem), it may be desirable to compute an average received percent and statistically determine how well it describes producers in the subsystem as a whole. A normative criterion can be compared to such an average to obtain an index of producer efficiency. However, it is often very difficult, or even erroneous, to identify such criteria. In fact, it may be easier to identify elements of the system that are causing the particular received percent by looking at the received figure in a nonnormative way.

3. Utilization

The consumer faces constraints which are analogous to those faced by the producer with respect to time and resource limitations. It therefore may not be possible for the consumer to actually utilize all the information received. That portion of received information that is normally put to use by the consumer is here termed "utilization". It is important to distinguish this term from the more general concept of utility. Utilization, as used here, is a percentage, proportion, or rate. Utility is a general value such as the computed "realized value" explained below.

The utilization value is expressed as a percent of the previously computed received value (i.e., from 0 to 100%). The consumer's ability to utilize information is clearly related to his information processing techniques, deadlines, availability of other supporting information, day to day modulations in information requirements, resource demands of other tasks, the degree to which real information is made clear by the format of the data, etc.

(4) 2.25 Received Value X .90 Utilization Value = 2.02 Realized Benefit

4. Feedback

Aside from the three postulated benefit factors, feedback might be viewed as one of the more critical determinants of information effectiveness. The role of feedback in the learning and human performance areas is well established.[6] However, most of this knowledge has been obtained in the simplified environs of the experimental laboratory. Little has been documented describing the influence of feedback on the effectiveness of information in a complex management system. Upon preliminary consideration, one is inclined to postulate a direct relationship between the extent of feedback and the perceived benefit concerning a given communication. A provision for obtaining data on feedback was included in the questionnaire to permit an assessment of whether inclusion of the feedback variable in the model resulted in its being strengthened.

5. Overall Benefit and Realized Value

Respondents are also asked to characterize the "overall benefit" they associate with the communication on a scale of 0 (none) to 4 (very high). This is explained as the respondent's perception to the benefit of the communication in general, taking into account everything he feels to be relevant (i.e., in place of, in addition to, or including the three

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[6]Literature in this area comes under the following headings: knowledge of results, feedback, reinforcement, information feedback, psychological feedback, reinforcing feedback, and reward. An overview can be found in D. H. Holding (reference 34).

factors of Potential, Received and Utilized). A test of the model thus becomes how useful the three factors (or their product, which we will term "realized value") are in explaining whatever it is that participants in the system perceive to be overall benefit.

Of course, realized value may be most appropriately calculated as some function other than a straight product. It may be a sum or nonlinear function. The exact nature of the algebraic function is important since it indicates relative roles of the independent variables and their weights. Unfortunately, the true nature of such functions is often not revealed until after years of model use. Nevertheless, the factors in the model can prove to be immediately useful in system analysis and development, given that meaningful correlations are present in the initial tests of the model. These considerations are discussed more fully in the findings section of this report.

Producer/Consumer Perspectives

As emphasized earlier, any respondent in the system may be a producer, a consumer, or both. The old adage of "the customer is always right" might be a bit too strong to characterize the interpretation of producer versus consumer views on a communication. The same would be true for "caveat emptor". Actually the two perspectives are complementary, and the technique presented in this report bases much of its strength on having both perspectives available for analysis and contrast.

Some important differences between producer and consumer-generated data should be made clear before proceeding. First, and most obviously, the producer-generated data will tend to be biased, in most cases, towards high ratings.[7] In interpreting the scales for outputs, the producer is asked to evaluate aspects of his own performance. In answering the question on received value (#2), he is directly assessing his (or his group's) effectiveness in generating the communication or output. While it is true that resource and time constraints could completely justify a low "received" score in a given case, considerable candidness is required. The producer is less personally involved in the "utilization" level.

However, some bias may enter into this factor from the standpoint of a producer wanting to maintain and thereby reflect a critical need for his services. Certainly the same sort of biases could be expected to enter into producer responses to the overall benefit question.

The most important hedge against these possible producer biases (aside from anticipating them) is that the primary assessment of benefit is made from the consumer-based data. The producer responses provide a secondary, though important, source of benefit data. The technique described in this report is at present intended for use in systems analysis type efforts. An essential requirement of such efforts is the location of problem areas in the system so that improvements can be specified and developed. Indeed, it is this need to locate problems that, to a great extent, prompts the need for a benefit measurement tool. However, having both producer and consumer perceptions about the benefit of a given activity, piece of information, or decision making process permits the identification of likely problem areas to the extent that agreement does not exist. This information, notwithstanding the precision of actual benefit measurement, permits the effective application of more

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[7] This tendency has been shown to persist in many studies which contrast self-ratings with "others" ratings. Prominent and long standing among these are the Ohio State leadership studies (reference 27).

intensive and specific analysis of a subsystem in need of integration or improvement. The opportunity for a much more favorable payoff ratio for systems analysis is thus created.

Another important difference between producer and consumer data is that, with the latter, it is possible to obtain average benefit perceptions on a given communication from the responses of the various consumers (usually more than one). This of course permits a greater reliability to be attached to the consumer data as opposed to what can be developed from the singular producer responses.

Benefits and Costs

The use of cost information provides a means of indexing the benefit ratings. The resulting "cost-effectiveness" indices permit a comparison of level of perceived benefit and at least some of the costs incurred to acquire that benefit. These indices, however, can only be used as standards of effectiveness throughout the system if appropriate weighting factors can be developed to scale benefit measures by relative organizational impact. Without such weighting factors, cost effectiveness comparisons *among* subsystems or system elements would have to be made with extreme caution, if at all.

On the other hand, even without the weights, the cost data give an indication of the magnitude of expense incurred in running the system. Additionally, it is possible to make cost-effectiveness comparisons *within* a system element or subsystem to the extent that homogeneity exists among its functions. Since the benefit measurement model is designed to locate sources of information deficiency or strength (i.e., its Potential, Received, Utilized, or feedback aspects), it is possible to imply much more from a cost-effectiveness index than what might be immediately obvious.

For example, if the overall or realized benefit for a given communication was low and costs were significant, a conclusion might be that elimination of the communication would improve system efficiency. However, by being able to examine the factors of benefit for that communication, it would be possible to determine whether, for instance, overall benefit was low, not because the kind of information was of little value, but rather because it was difficult to produce or utilize (e.g., P = 4.0, R = 70%, U = 25%). With this information, it would be possible to see that a more appropriate system development strategy would bolster utilization capabilities (e.g., through the addition of more staff, adding ADP capability, or maybe just reformatting the output). Alternately, in a case where P = 1.0, R = 95%, U = 95%, it would be indicated that this communication is not an important item for the system. Associated cost data would reflect how much could be saved or redirected through the elimination of the item.

1. Nature of Costs in the System

Theoretically, there are costs associated with establishing, maintaining, and executing the communications in a system. In a management system, unlike hardware systems, establishment costs are not high relative to the other two types. In fact, once this kind of cost is amortized over the first few years of the communication's existence, it becomes quite small. Maintenance costs, while certainly existent in this system, tend to be hard to distinguish from execution or operation cost, except in cases of clear cut liaison functions. For the most part, communications are maintained in the system by virtue of their continuous execution.

We are thus left with operation or execution costs which primarily takes the form of manpower expenditures – staff. There are cases of course in which substantial data

processing costs are incurred in the system. These costs are usually reported as such and it is not necessary to devise a data collection strategy for them. Labor costs associated with the functions of the manpower system are, however, often difficult to cull out of the total staffing budget. Naturally, for many system elements, establishing manpower requirements is but one of several functions to be performed. Conventional accounting procedures do not normally aim to segment costs attributable to these various functions within the same system element. Indeed, even if such an aim existed, it would be virtually impossible to accomplish, since these particular kinds of cost would not be expected to occur in any discrete or consistent way.

2. Cost Data

It was decided that cost estimates adequate for benefit contrast could be obtained by relying on accounting records for cost rates and on management reflection for amounts of resources expended. After considerable analysis of staffing data relevant to the largest sector of the system to be studied (i.e., OPNAV), four categories of labor costs were identified on a man-year basis. These costs include salary, leave, benefits, training, and retirement. Means for each category were computed for each branch in the OPNAV organization. Grand means for each of the labor cost categories appear below:

Labor Category	Average Life Cycle Cost (per man-year)
Officer	$56,000
Enlisted	19,500
Civilian Professional	27,670
Civilian Clerical	11,360

The officer cost figure was computed using the current (30 Nov 1973) roster of officers within the OPNAV sector of the system and the cost rates included in the Navy Military Manpower Billet Cost Data manual (reference 11). With this, as with the other cost categories, salary adjustments were made to reflect pay raises of October 1973 where necessary. The roster permitted a determination of officer mix (rank and designator) by organizational element. Differences among pay rates for various designators within a rank were reflected as permitted by the data in the references.

It was not possible to identify actual enlisted on board by organizational element. Ordinarily, this would be reflected in a Manpower Listing, however, none has been currently produced for this organization (OPNAV). Authorized manpower by organizational element was available (reference 12). Therefore, the authorized figures were used to approximate actuals in order to obtain a reasonable mix of rates and ratings on which to base an average cost figure. Again, life cycle costs (reference 11) were useful in computing the cost rates.

Clerical civilian costs were differentiated from professional civilian costs by considering the latter to be pay grades GS-7 and above. In so doing, of course, certain professional were counted as clerical and vice versa. Current pay rates for both clerical and professional were obtained from civilian payroll listings (December 1973), by individual and organizational element. Non-salary costs were computed by using current formulas which compute them as 30% of salary figures (identified through SECNAVINST 7000.14 and consultation with representatives of the Navy Comptroller's Office and the Office of Civilian Manpower Management (OCMM)).

Grand means shown were used for each of the four categories since deviations from these means attributable to organizational element affiliation were relatively small. (A minor exception to this was civilian professional costs. However, the differences were still not large enough to warrant the use of separate averages for each organizational element with respect to this category.)

These rates are to be applied against amounts of labor in the four categories which management estimates to be expended for a given manpower requirement communication. This information is, of course, being gathered from the point of view of the producer only. Each organizational element is asked to estimate the number of man years of each category expended on each product or output (Parts VI.c and VI.d of Appendix A). These figures are then multiplied by the appropriate cost rates and an estimate of total cost for the communication is attainable. Producers are also asked to give an ideal man year/category mix for each product if it is felt that the current situation is less than optimal. By comparing cost based on such ideal staffing with actual cost, it may be possible to discover whether improvements to the system can be made without the requirement for significant additional expenditures. The difference between actual and ideal configurations can also be compared to benefit ratings to see whether there is a relationship (e.g., a low "Received" rating and a wide divergence in the producer's perception about his actual versus ideal staff).

The basic analysis factors to be derived from the costing data are total cost, shared cost, cumulative product cost, and message cost. Total cost is the product of labor expended and cost rates for any given output (communication). When this figure is divided by the number of consumers of that output, a *shared cost* figure results. *Message costs* are obtainable by dividing the periodicity of the output (e.g., twice a month) into the shared or total costs. Cumulative costs are totals of either shared or total costs associated with a set of products that form a path of development for a common major system output. For example, many products go into the development of the Program Objectives Memorandum (POM). The cumulative cost of these products would be the aggregate of their total costs. As related to cumulative cost, total cost might be thought of as reflecting *value added.*

Sufficient results have not been tabulated from collected data to allow for a preliminary evaluation of the approach in the cost area at this time. This description is included merely to indicate the nature of the data that will be used to complement the benefit findings. The costing methodology is not proffered as a particularly innovative achievement. It is only one way among many to attain rough estimates of relative cost for information production. Other techniques, such as reflecting more of the cost of receiving as opposed to producing information, are certainly possible. Such costs are obviously mixed into the kinds of cost obtained through the approach presented. However, it is easy to overlook the fact that a low production cost does not necessarily indicate that total cost relative to the communication is low. Each manager receiving the information must allot time and hence cost for its consideration. This complementary cost is of comparable importance.

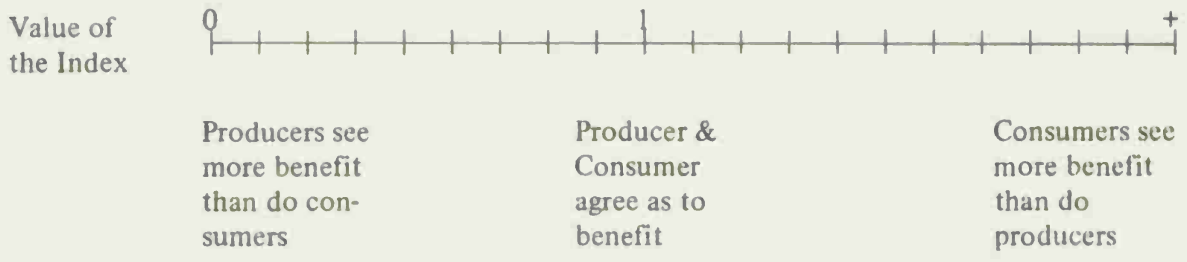
Application of the Model and its Derived Measures

Only the most direct uses of models have been presented thus far. However, the approach paves the way for a number of other developments that either support or build upon the basic model. Several indices, in addition to the fundamental cost benefit measures, provide analytic insights to the system being studied. For example, *congruence indices* can

be formulated to reflect differences between producer and consumer views concerning potential, contribution, received value, utilization, etc. In the case of realized value, the index would be developed as follows:

$$\frac{\text{Consumer's perception of realized benefit}}{\text{Producer's perception of realized benefit}} = \text{Congruence Index}$$

and would be interpreted,



These kinds of consumer/producer ratios can be extremely powerful and resilient developmental tools, since the congruence measure serves a purpose somewhat independent from its cause-effect meaning. (This point was elaborated upon on pages 14 and 15.) The index is not free of the difficulties of perceptual set. That is, while a given index may be greater or less than one, this difference may only be showing disagreement over what constitutes "high benefit" as opposed to disagreement over the actual effect of the communication. The producer and consumer may be in agreement over this latter point. Still, the congruence index can serve a valuable role from the system development standpoint by simply identifying such disagreement, be it over the effect, the value of the effect, or both. Once the lack of congruence has been identified, further steps can be taken in developmental efforts to iron out whether there is a requirement for a change in performance, a change in performance specifications, or both. Aside from this, it will be valuable to perform analyses on the responses to ascertain systematic differences in amplitude of ratings among respondents.

Realization/Potential Ratio. Another fairly straightforward indicator of system development potential is the relationship of potential benefit to the realized benefit as measured by the three-factor product PRU.

$$\frac{\text{Realized Benefit}}{\text{Potential contribution}} = \text{Index of Potential Realized (0 to 1)}$$

It may also be possible to develop curves that interrelate potential, received, and utilized aspects of information, as well as other characteristics such as feedback, format, etc. These curves may be useful in the area of information theory and processing and the econometric analysis of factors influencing demand and supply of information in organizations.

Development of Attribute Based Models. It may be possible to extend the "PRU" approach to benefit in order to incorporate the identification of attributes of effective (and ineffective) planning and programming practices. The model presented in this report differs substantially from models based on expectancy theory (references 28, 72) in that the latter focus on attributes. The PRU benefit model does not directly attempt to identify attributes

associated with effectiveness or ineffectiveness, but rather focuses on the performance aspect. The rationale behind this approach is that the application of an attribute-based model would be inappropriate at the initial organizational diagnosis stage (e.g., Phase I MARRCS). Organizations are largely based on the principle of differentiation.[8] We find distinct subunits developing in organizations mainly because the units are performing different kinds of functions and have somewhat different demands with respect to operational environment, raw materials, technology and the like. An attribute based model for use in the initial organization diagnosis stage would have to be broad enough in scope to encompass significant and distinct subunits. In using the more general approach to benefit assessment described in this report, accompanied by a comprehensive system descriptive effort (Appendix A), it will be possible to establish the necessary background for constructing attribute-based models in the future. These should prove more capable of being responsive to the unique characteristics of each individual problem setting. Common threads underlying many system problems would also become easy to identify.

In summary, the attribute approach would be more effectively applied once it is possible to construct fairly homogeneous sets of communications. Table 1, previously presented, indicates how homogenization might be accomplished by way of a typology. More generally, the nature of the questions included in Appendix A reflects the kinds of data segmentations that can be accomplished with the information being collected in Phase I MARRCS. It will be possible to compose subsets of communications by applying descriptive, analytic, evaluative, and taxonomic criteria, as well as any combination of these, to the communications identified in data collection. A highly sophisticated interactive data analysis program (TISA) has been designed and developed for this purpose.[9]

The findings presented in the following section are the results of analyses of early questionnaire returns. It was not possible to apply the techniques discussed above to increase homogeneity of communications in this preliminary analysis (except to the extent that producer-consumer groupings were made). Hence there was an undetermined amount of heterogeneity among the communications on which the analyses of the following chapter were based.

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[8]The differentiation-integration idea is nicely developed in the work of Paul Lawrence and Jay Lorsch (reference 42).

[9]TISA (Technique for Interactive Systems Analysis) is an information analysis system that has been specifically developed to meet the objectives of Phase I MARRCS but has inherent general applicability in the organizational analysis area. TISIA will be comprehensively documented and explained in reference 20.

FINDINGS

Preliminary analyses were performed using a total of 145 observations that were obtained by applying the data-gathering instrument (Part VIII, Appendix A) in limited parts of the Navy's manpower planning system. Of these 145 observations, 80 were made by respondents from their viewpoint as information consumers and 65 were made as information producers. The observations were made by a total of 18 respondents who were by and large each commenting on several communications. These data constraints did not satisfy the conventional independence assumptions of statistical techniques such as regression and analysis of variance. Hence, little could be gleaned at this point regarding the statistical significance of the various components of the benefit model presented. However, given the magnitude of data being collected in the Phase I MARRCS study, it will be possible to obtain such measures in the near future.

Examination of the model has been, and will continue to be, performed across different kinds of communications since there might be at most only five or six consumers of the same communication and usually only one producer. However, as pointed out above, it will be possible to utilize the information typology presented earlier (Table 1) as well as other means to compose data sets that share more homogeneous perceptual objects. The heterogeneity of the communications used in the preliminary analysis is viewed as a probable detraction from the strength of the relationships that were uncovered in that analysis. It is postulated that the increased segmentation of the incoming data will contribute to the strength of the model's relationships.

Preliminary Results

With the data constraints described above, the basic objective of this preliminary analysis was to obtain an indication of how helpful the hypothesized benefit factors – Potential (P), Received (R), and Utilization (U) – could be in explaining whatever it is that participants in the system consider to be the overall benefit (OB) of information. Multiple regressions, correlation, and analysis of variance were used in a descriptive sense and within the data limitations pointed out above.[10] Certain trends in the data are worthy of note.

Indications are that of the three postulated benefit factors, Potential Contribution is most strongly related to Overall Benefit. P tended to have the largest regression coefficient and highest correlation with OB (Table 2). The regression coefficient for P ranged from .402 to .660, depending on whether the data set was comprised of (1) producer only, (2) consumer only, or (3) producer and consumer data. The highest regression coefficient for P resulted from the consumer only data, while the lowest resulted from the producer only data. The correlation coefficient for P vice OB was highest (.642) for consumer only data.

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[10] Another possible limitation is one which pertains to virtually all practical applications of regression analysis to real world problems. This is the presence of error in the dependent as well as independent variables. The implications of this are discussed in reference 73. However, the limitation may be largely irrelevant to this particular problem since we are trying at this point to determine the factors of *perceived* benefit, not real benefit in some abstract sense (see Figure 1). The distinction is briefly addressed in reference 36, p. 283.

TABLE 2

SUMMARY OF REGRESSION ANALYSIS RESULTS

	Constant	Potential	Received	Utilized	Computed Benefit	Feed-back	R-Squared
Producer and Consumer Data:							
Correlation with OB		.610	.423	.405	.549	.069	.407
Regression Coefficient	.576	.598	.125	.047	–	–	
Standard Error	.129	.086	.058	.042			
Consumer Only:							
Correlation with OB		.642	.395	.478	.550	-.104	.414
Regression Coefficient	.478	.660	.048	.059	–	–	
Standard Error	.191	.126	.080	.064			
Producer Only:							
Correlation with OB		.569	.617	.264	.635	.342	
Regression Coefficient	.933	.402	.542	.117	–	.115	
Standard Error	.167	.110	.108	.055			.518 (with feed-back, .556)

The Received Value factor showed the next highest regression coefficients, the highest of the three data sets being for the producer only data (.542). That same data set produced the highest regression coefficient between Received Value and Overall Benefit (.617). For this preliminary data, Utilization Value seemed to be the factor least related to Overall Benefit both in terms of its regression coefficient and its correlation coefficient (.117 and .478 respectively in the best case).

Realized or Computed Benefit, the product of the Potential, Received, and Utilization factors, best correlated with Overall Benefit in the case of producer only data (.635). That set of data also produced the best line fit for OB = f ($P \times R \times U$); R-Squared was .518. The majority of regression coefficients obtained were roughly three to seven times their respective standard errors. This degree of variability was judged as not excessive given the intended use of the model, its environment of application (i.e., many different communications with only a few observations on each), and of course pending a comprehensive statistical analysis of the complete data set presently being collected.

The dominance of the Potential Contribution factor might be indicative of its being the most important of the three postulated factors with regard to the benefit of information. This has intuitive appeal in that P can be thought of as determining the size of the benefit "pie", and hence the relative size of any proportional "slice" from it. Also, conceptually, it is an absolute amount (unlike R and U, which are relative) and is very much like OB. Consequently, it is the only one of the three factors that is measured on the same scale as OB. Somewhat related to this point but more in the area of scale design is the possible explanation that P tended to be most closely related to OB because they were both measured on an integer 0 – 4 scale, whereas R and Uwere measured in terms of more nearly continuous variables. In future tests of the model, it will probably be more effective to normalize the scales for all the independent and dependent variables. Another constructional aspect which may have contributed to the dominance of P is the fact that, within the context of Appendix A, it was always the first benefit item to which each subject was exposed. Thus, subjects may have tended to transfer their most immediate and indicative benefit perceptions via this first factor. It may have been that, in spite of the previewing nature of the introduction to the benefit questions and the specific wording of each of these questions, subjects did not realize fully that factored (as opposed to holistic) benefit responses were being requested until they reached the Realized Benefit or the Utilization Value questions. These possible constructional problems may have similarly contributed to the dominance of the R variable over U. It should not prove difficult to test these alternative explanations in future applications of the model.

Differences in regression and correlation coefficients that occurred in the analysis of producer only and consumer only data should be noted. The consumer only data resulted in relatively miniscule regression coefficients for R and U, while the coefficients for the producer only data were much more evenly distributed over the P, R, and U factors. The dominance of the Received Value factor in the producer only data could be attributed to the self-rating bias referred to earlier in this report, (pages 14 and 15). In answering the received value question, respondents were directly evaluating their ability to produce the communication, given existing time and resource constraints. An analogous explanation does not seem possible in the case of the consumer only data, where one would have expected a corresponding dominance in the Utilization Value factor. The data base presently being compiled will permit a determination of the statistical significance of the difference between producer and

consumer responses. At present, the comparison of factor means exhibited in Table 3 is as much as the preliminary data will permit in the way of a statistical analysis of variance.

TABLE 3

PRODUCER VERSUS CONSUMER DATA*

	Producer Data (Mean)	Consumer Date (Mean)
Potential Contribution	3.169	3.261
Received Value (percentage)	.852	.762
Utilization Value (percentage)	.821	.791
Overall Benefit	3.06	3.14
Feedback	1.615	1.169

Scales:

Potential Contribution
Overall Benefit:

- None – 0
- Low – 1
- Moderate – 2
- High – 3
- Very high – 4

Feedback:

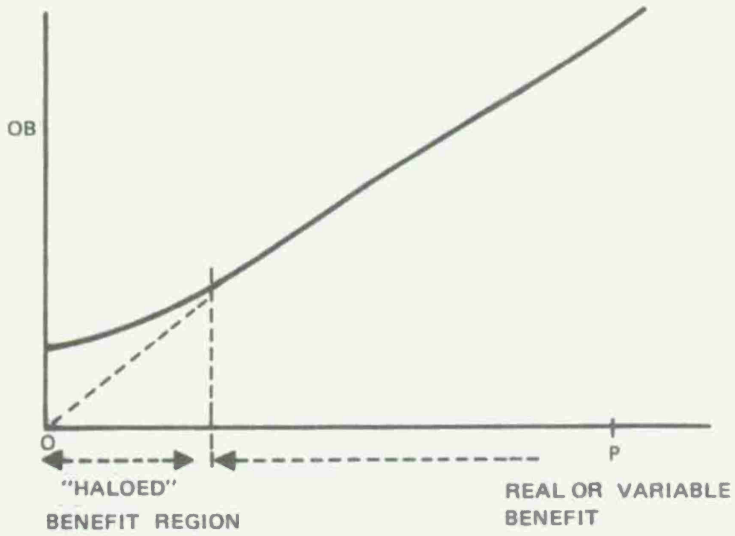
- None – 0
- Sometimes – 1
- Most times – 2
- All the time – 3

Received Value
Utilized Value: 0–100%

*The purpose of this table is to indicate how the regression analysis results may have been influenced by systematic differences in producer vs consumer data. Since producers and consumers were responding to nonidentical sets of communications, differences in the means do not necessarily reflect differences in the way producers and consumers view (the same) data. This kind of analysis will be possible once Phase I data collection is complete.

Another difference between the producer only and the consumer only data is to be noted in the value of Y-intercept or constant term in the regression results (Table 2). The constant for the producer only data is almost twice as much as that of the consumer only version. This again could be an indication of a self-rating bias on the part of producers evaluating their own performance. Additionally, the existence of a sizable constant in both the producer and the consumer cases could indicate that, regardless of P, R, or U values, OB tends to have some minimum value that is substantially above zero. This could occur either because there is, in fact, some minimum nonzero benefit accrued from virtually all information or because respondents are reluctant to go as far as to report that no benefit is derived

from an object of their (or another organization's) endeavors. Of course, the demarcation between this latter fixed or "haloed" type of benefit attribution and the more variable type of benefit that might be explained by P, R, or U is likely to be continuous as opposed to discrete in nature. Such a possibility is graphically approximated below.



Alternative Model Interpretations

This report has primarily attempted to show how the benefit of information may be effectively conceptualized and measured in terms of its essential functional parts as thought of in a system setting. A functional model for the relationship has been postulated as OB = f (P X R X U). It has not been possible to statistically test the validity of this function with data available at the time of this writing, though such tests will be possible in the near future. However, the validity of this particular function is viewed as being secondary to the identification and development of the Potential, Received, and Utilization factors themselves. In fact, with these three factors, a number of other functional relationships may be postulated that are either alternatives to OB = f (P X R X U) or contribute additional meaningful insights to the benefit of information in management systems.

For example, the three factors P, R, and U are proffered as a more specific and meaningful way of determining benefit than more holistic evaluations of overall benefit. Thus one might expect a substantial divergence between the product of factored benefit and an overall benefit estimate (i.e., the factored benefit being more accurate than the overall). This relationship would seem to be testable only within a rigorously controlled decision making environment in which the actual value of each information module has been determined beforehand. This approach is discussed more fully in the Conclusions and Recommendations

(pages 29 and 30). Another such approach would be to view the three factors as an inclusive representation not of overall benefit but rather of only those aspects of benefit with which one is concerned for some system development or management purpose. In this case, one would not be denying the existence of other benefit factors but intentionally excluding them from consideration in the problem at hand on the basis of relevancy. (In a system decision, one might desire to exclude perceived factors of benefit that individuals include in their consideration of overall benefit that are made on the basis of benefit solely to themselves rather than to the larger system.)

Another alternative approach to the three factors is to view them more as a way for people to better conceptualize and communicate feelings about information benefit in the future, than as a way to factor and quantify corresponding reports of overall benefit at present. That is, a learning curve may be involved wherein people become better able to use the PRU construct presented them as a way of describing benefit the more they use it. Such an hypothesis could be tested with the data presently being collected. Again the OB = f (P X R X U) model would be used as a basis. Comparisons would be made between benefit evaluations for the subject's first and last responses. Since each respondent reports on an average of about 15–20 communications, a systematic difference in response patterns due to the first and last consideration may be discernible.

It may also be that benefit measurement and analysis are best approached through separate functions for the information producer versus the information consumer spheres. The P, R, and U factors may be useful for both of these kinds of information but each might have a distinct functional relationship of its own. Analysis of variance due to the consumer/producer property will be performed with the data presently being collected to determine its statistical significance. Separate regression equations will also be obtained for each of these sets. Along similar lines, it may be possible to identify distinct functional relationships of P, R, and U to OB for other kinds of data segmentations. Some candidate criteria for these segmentations are format, tone, direction of information flow (up, down, lateral), cost to produce, and frequency. The viability of including such properties as variables in the regression equations will be ascertained. The improvement in line fit obtained when the feedback variable was included in the regression function (Table 2) may be viewed as an indication of the potential of this approach.

Dropping down to an even greater level of specificity, an analysis of systematic differences across individual respondents' perceptions of the relative weights of the three factors seems warranted. It may be that a more accurate relationship between PRU and OB could be obtained if respondents also weighted the three factors in terms of their relative importance or impact on OB. There is a possibility, of course, that respondents are already reflecting such weights in their ratings (i.e., when a respondent rates P as very high, it is a reflection that P is both important and very high for that particular information item). There are at least two aspects to this consideration: (1) Do ratings of P, R, and U vary systematically from one respondent to another? (e.g., Respondent 1 views P as very important for all his communications; and Respondent 2 tends generally to view it as moderately important), and (2) Do ratings of P, R, and U vary systematically with respect to type of information being considered? If so, could these variations be better reflected by having respondents both weight and rate P, R, and U for each communication?

Another aspect of this approach which should be explored is the relationship of respondent's *tenure* to the results obtained by using the model. Tenure was a separate

response item in the questionnaire (Appendix A). The instrument was directed towards people who had a considerable amount of experience in the system. This was considered necessary in view of the detailed functional descriptions and evaluations that were requested. In many cases the respondent was required to reflect over his past experiences with an input or output and make a summary reaction about one of its information characteristics. However, tenure was not stringently controlled as a respondent criterion. While it is unlikely that a respondent with less than 6 months of intensive experience in the subject function could have successfully completed the questionnaire, a considerable range in respondent tenure beyond that level will probably be reflected in the data presently being collected. This range should permit a viable evaluation of this aspect of the model. The postulated benefit factors should prove most meaningful in cases where individuals have the necessary base of experiences upon which to draw evaluations. The data will also be present to make a similar analysis with regard to the specific longevity of each communication.

Finally, the system of application itself should be considered in terms of its effect upon the nature of the relationship of P, R, U, and OB. The point here is that major differences among systems or organizations, as evidenced by their objectives, methods of operations, external environments, education and background of members, etc., could warrant somewhat different interpretation and usage of the benefit factors. Future applications of the approach should be able to explore this possibility.

CONCLUSIONS AND RECOMMENDATIONS

· The approach presented in this report is viewed as a significant advancement in dealing with the problem of benefit measurement and analysis in humanistic systems.

The constructs, as thus far developed, are admittedly primitive. Nevertheless, a foundation is provided upon which to systematically build and refine a technique of great potential utility to soft system developers and managers. The research community also stands to profit from the development of this technique since our present ability to state the benefit/cost implications of current or proposed R&D is far from satisfactory.

· A programmatic approach to this problem area, using the benefit factors developed in this preliminary study, is recommended. a preliminary remark; a forward"

POMPOUS BULLSHIT

This report can serve as a prolegomenon to such a program, having identified pertinent research questions as well as possible methods for their resolution. These research questions, which have been discussed in the section above, are summarized below:

1. Are the benefit measures obtained with the model more reliable and valid than holistic benefit estimates? (i.e., Is PRU a better measure of benefit than OB?)

2. Is the structure of benefit specific to the nature of the information? (i.e., Do distinct benefit functions emerge from groups of communications that have been segregated on the basis of homogeneity?)

3. What is the statistical significance of differences between producer and consumer evaluations of information benefit? Is it most appropriate to use different benefit functions in each of these spheres?

4. Is there a learning curve applicable to the use of the P, R, and U factors and their input/output context? If so, what is the nature of this curve? (e.g., How much better do the three factors measure benefit once a respondent feels comfortable with their usage, as opposed to a first exposure to them?)

5. What is the relationship of factor ratings to tenure of the respondents in their current positions? How do the ratings relate to the length of time the communication has been consumed or produced?

6. Which properties of information, when incorporated into the PRU function, result in improvement? Which properties seem unrelated?

7. Does a weighting of the factors, based on individual respondent views of relevant importance, increase the strength of the model? What is the effect of such weightings as they might be applied on a communication by communication basis?

8. Does a "haloed" benefit exist for producer or consumer ratings and, if so, how should it be interpreted? (e.g., Should it be discounted as irrelevant to system level decision making?)

9. What are the results of alternative scale designs for the benefit factors? (e.g., Would the relative magnitude of the coefficients change if P and OB were put on the same scale as R and U?)

10. What are the results of changing the response order of the benefit factors in the instrument? (i.e., Is P the dominant factor mainly because it is identified first?)

11. Should the model be modified on the basis of differences in system characteristics? What is the mechanism for accomplishing such modifications?

The order of the above questions does not necessarily imply precedence. Nor are the questions mutually exclusive in every case. They do imply the need for a program that features development through real world application, with a capability for laboratory experimentation to answer questions that require strictly controlled problem environments. The most critical ingredients to such a program – real world test beds for model applicability and utility – already exist within NPRDC's Managements Systems program area. The MARRCS Phase I study is an excellent example. It is recommended that such elements be integrated with the necessary laboratory experimentation to form a systemic program of research in this area.

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APPENDIX A
MANPOWER/PERSONNEL PLANNING QUESTIONNAIRE

APPENDIX A
MANPOWER/PERSONNEL PLANNING QUESTIONNAIRE

Introduction

This project is being conducted by the Navy Personnel Research and Development Center (NPRDC) as part of its mission to perform research and development in the areas of personnel management and manpower planning. CNO letter of 30 November 1973 points out the need to collect data from within the current manpower planning system and asks for support of the project.

The purpose of this particular effort is to obtain a thorough description and analysis of the processes through which the Navy currently manages manpower, especially those processes and decisions related to the POM (Program Objective Memorandum) or PPB cycle. This analysis is intended to provide a solid foundation for future developmental efforts in the manpower area both at the Center and elsewhere in the R&D community. The data collection phase of the effort also represents an opportunity for people in the manpower planning system to contribute their observations to the system development effort. This questionnaire is in no way a comprehensive job analysis or desk audit, nor does it content permit such a usage.

The questions are based on an information flow concept. The major functions that you perform or products that are produced are looked upon as "outputs" or "communications". The various types of information that are used to produce these products are considered "inputs" or incoming communications. The manner in which these inputs are used in order to produce the outputs is referred to as the process or processing technique. The format is designed to systematically ask questions in each of these three areas. If your function has a large number of inputs or outputs that are basically similar in form, purpose, source or destination, they may be grouped and referred to as one. It is reemphasized that you are being asked only to respond with regard to manpower/personnel planning and decision making information that you use or produce.

It is well recognized that the effort required to complete this questionnaire is no small task. Your consideration and cooperation is greatly appreciated. If any problems arise in completing the form please call 433-2706 or 433-2617 (area code 202) and we will be happy to assist you.

NPRDC, Washington Branch Office, Washington, D.C.

I. **Background Information**

Date: _____

Name of Respondent: _____

Length of Time in Present Position: _____

_____

Name of Organization, Group or Position being described: _____

_____

_____

_____

Name of next lower Organization level: _____

_____

_____

_____

Name of next higher Organization level: _____

_____

_____

Number of years your function has existed: _____

_____

Other identifying information: _____

_____

_____

_____

II. Identification of Inputs, Processes and Outputs

Throughout this questionnaire you are asked to describe (1) information or actions you produce (output); (2) techniques you utilize to produce them (processes) and (3) information upon which you base your outputs (inputs). Since it would be cumberson to repeatedly name all of these items, you are asked to list them below as indicated and thereafter refer to them by their letter or number code. (An example is provided on the following page.) Again, list only items with manpower/personnel planning implications. Provide as many items as you think appropriate. Brief names for each item will be adequate since space for more detailed descriptions is provided in the next section.

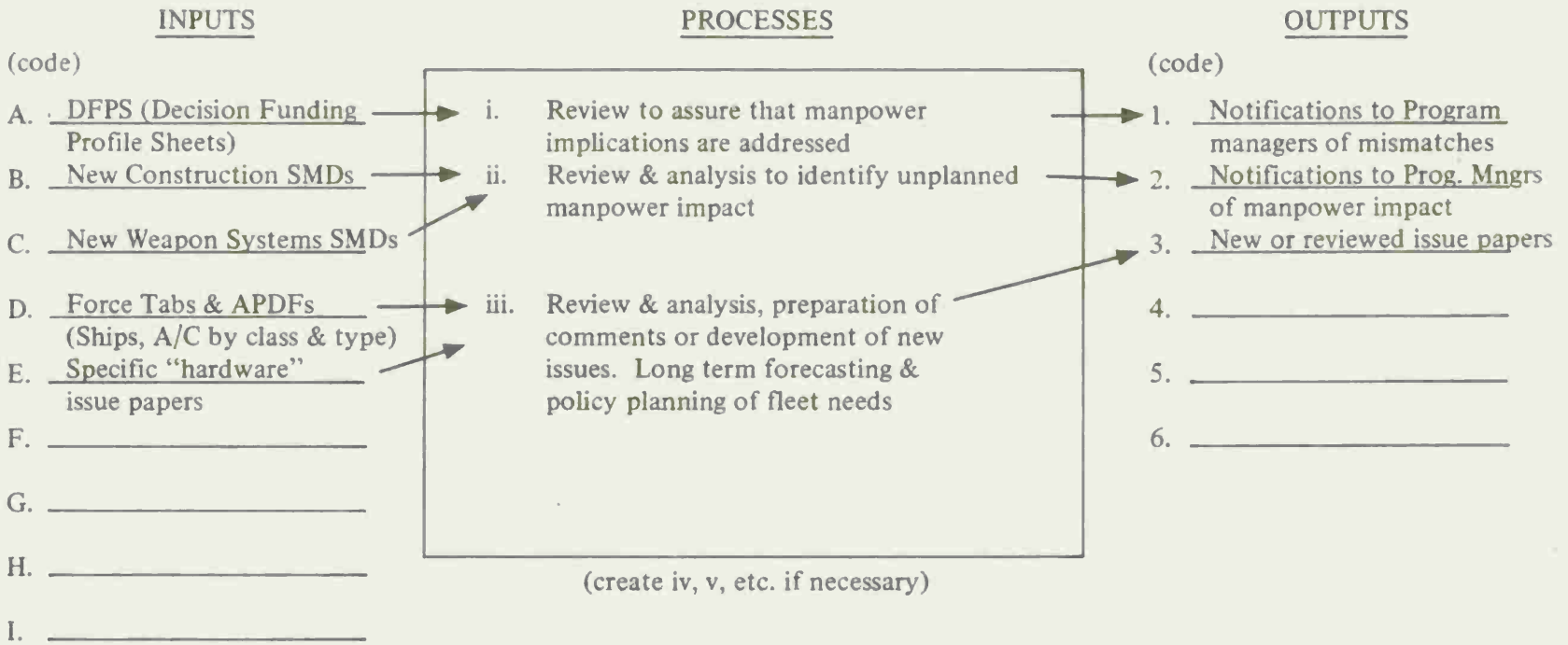
INPUTS (code)	PROCESSES	OUTPUTS (code)
A. _____		1. _____
B. _____		2. _____
C. _____		3. _____
D. _____		4. _____
E. _____		5. _____
F. _____		6. _____
G. _____		
H. _____		
I. _____		

(create iv, v, etc. if necessary)

Once you have completed the lists, please indicate which inputs are associated with which processes by using arrows. Similarly connect each process with its associated product(s) or outputs. An example of this identification process is also provided on the next page. Once completed, this identification page should be pulled out so that the coding system (A, B, C; 1, 2, 3; i, ii, etc.) can be easily used in the rest of the questionnaire. Please remember to enclose this sheet when returning the questionnaire.

II. (Continued)

Simplified Example of Input-Output Flow



III. Input, Output and Process Specification

Briefly describe the content of each input, process and output identified. Indicate sources and destinations for inputs and outputs respectively. Also, indicate number of years produced or received.

INPUTS

A. _____

_____

Source of Input: _____

_____ Years Received: _____

B. _____

_____

Source of Input: _____

_____ Years Received: _____

C. _____

_____

Source of Input: _____

_____ Years Received: _____

D. _____

_____

Source of Input: _____

_____ Years Received: _____

E. _____

_____

Source of Input: _____

_____ Years Received: _____

F. _____

_____

Source of Input: _____

_____ Years Received: _____

G. _____

_____

Source of Input: _____

_____ Years Received: _____

H. _____

_____

Source of Input: _____

_____ Years Received: _____

I. _____

_____

Source of Input: _____

_____ Years Received: _____

(Continue on back if necessary)

PROCESSES

i. _____

_____

_____ Years Performed: _____

ii. _____

_____

_____ Years Performed: _____

iii. _____

_____

_____ Years Performed: _____

(Use back of this page for additional processes, if necessary)

OUTPUTS

1. _____

_____

Destination: _____

_____ Years Produced: _____

2. _____

_____

Destination: _____

_____ Years Produced: _____

3. _____

_____

Destination: _____

_____ Years Produced: _____

4. _____

_____

Destination: _____

_____ Years Produced: _____

5. _____

_____

Destination: _____

_____ Years Produced: _____

6. _____

_____

Destination: _____

_____ Years Produced: _____

(Continue below and on back, as necessary)

IV. Classification

In the grid below, indicate which categories apply to the inputs and outputs you have listed. Multiple categorizations, are of course possible. Indicate applicable categories with a check (✓) under appropriate column code.

	Inputs									Outputs					
	A	B	C	D	E	F	G	H	I	1	2	3	4	5	6
Is the information in any way															
a. a scenario, projection, forecast, or contain "what if" questions or answers?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
b. a review, evaluation, feedback, sanction, concurrence or nonconcurrence, reclama?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
c. an identification of variables, factors, or problem elements; or a structure for considering them?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
d. quantitative information, numbers associated with problem elements?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
e. a direction, statement of policy or procedures to be followed?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
f. a specification of available resources or resource constraints?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
g. a documentation of a processing method, technique, approach?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
h. best described by some other category? If so, what? (state category below and make (✓) at right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

_____

V. **Description**

As in the last section, check the appropriate column(s) at right for each category at left that applies.

			Inputs								Outputs					
			A	B	C	D	E	F	G	H	I	1	2	3	4	5	6
The information is:																	
Format	a.	Prescribed (formal)?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	b.	Written?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	c.	Routine?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	d.	Request?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	e.	Response?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Tone	f.	A suggestion?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	g.	A recommendation?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	h.	Guidance?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	i.	A directive?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	j.	A command?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Frequency	k.	Reported yearly?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	l.	Reported monthly?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	m.	Reported weekly?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	n.	Reported on request?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Characteristics	o.	Accompanied by substantial informal dialogue?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	p.	WIDELY VARIABLE IN KIND OR QUANTITY (i.e., ± 20% OR MORE) FROM YEAR TO YEAR?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

VI. Resource Utilization

Enter the appropriate number or check in each column for the following questions.

	Inputs								
	A	B	C	D	E	F	G	H	I
a. The approximate accuracy of this information is . . . enter (✓)									
Not accurate	☐	☐	☐	☐	☐	☐	☐	☐	☐
Accurate some of the time	☐	☐	☐	☐	☐	☐	☐	☐	☐
Accurate most of the time	☐	☐	☐	☐	☐	☐	☐	☐	☐
Always accurate	☐	☐	☐	☐	☐	☐	☐	☐	☐
b. The wait time for this information or action is . . .									
Not satisfactory	☐	☐	☐	☐	☐	☐	☐	☐	☐
Satisfactory some of the time	☐	☐	☐	☐	☐	☐	☐	☐	☐
Satisfactory most of the time	☐	☐	☐	☐	☐	☐	☐	☐	☐
Always satisfactory	☐	☐	☐	☐	☐	☐	☐	☐	☐

	Outputs					
	1	2	3	4	5	6
c. The appropriate man years spent on each output in a year. Enter number of man years for each of the following as appropriate.						
Officers	____	____	____	____	____	____
Enlisted	____	____	____	____	____	____
Civilian professional	____	____	____	____	____	____
Civilian clerical	____	____	____	____	____	____
d. If you believe a different distribution of manpower resources would be more effective in producing the outputs, describe the distribution.						
Officers	____	____	____	____	____	____
Enlisted	____	____	____	____	____	____
Civilian professional	____	____	____	____	____	____
Civilian clerical	____	____	____	____	____	____

VII. Process

A. Are the outputs that you have identified produced over time as part of a cycle (e.g., the POM or some informal cycle)?

	Yes	No	Do Not Know	If Yes, Name of Cycle	Cycle Length If Known
Output #1	☐	☐	☐	_____	_____
Output #2	☐	☐	☐	_____	_____
Output #3	☐	☐	☐	_____	_____
Output #4	☐	☐	☐	_____	_____
Output #5	☐	☐	☐	_____	_____
Output #6	☐	☐	☐	_____	_____

B. For the outputs that are part of cycles, what event or communication in the cycle initiates production or submission of the output(s)? Also indicate these "triggers" (if any) for any outputs that are *not* part of a cycle.

Output #1 _____

Output #2 _____

Output #3 _____

Output #4 _____

Output #5 _____

Output #6 _____

VII. **Process (Continued)**

C. **Sponsor:** Categorize the output(s) according to the appropriate "sponsor" context. A given output can occur in more than one of these contexts. If you are not familiar with the sponsor context of an output(s), indicate below in item 10.

	Output # (code)	Name(s) of Mission Program, etc.
1. Produced as a *major* mission sponsor requirement	_____	_____
2. Produced as a *force/function sponsor* requirement	_____	_____
3. Produced as an *appropriation sponsor* requirement	_____	_____
4. Produced as a *program element sponsor* requirement	_____	_____
5. Produced as a *Navy wide support sponsor* requirement	_____	_____
6. Produced as a *Program sponsor* requirement	_____	_____
7. Produced as a *Military Manpower Claimant* sponsor	_____	_____

8. Other (Specify)

9. If any of the outputs are related to OCMM, briefly specify the relationship.

_____

_____

_____

10. Not familiar with sponsor context of the following output(s): (List appropriate outputs by code)

_____

_____

_____

VII. Process (Continued)

D. For each process, specify the problem solving technique used. Well known techniques such as PERT-CPM, linear programming, regression, etc., need only be named. Techniques that you cannot label with technical terms should be briefly described.

PROCESS

i.

ii.

iii.

(Continue on back of page if necessary)

VIII. Benefits

In this section you are asked to estimate certain benefits associated with inputs and outputs you have identified. Four types of estimates are requested, potential contribution, received value, utilization value and overall benefit. Definitions and appropriate scales for each are given below. The estimates should be entered in Table VIII according to the input/output codes (A, B, C, etc.,/1, 2, 3, etc.). Fill in all input columns first, then go to outputs.

- Potential Contribution (Column 1)

For *inputs*, this is your estimate (perception) of the contribution the input would make to your output(s) if it were perfect and you were free to make full use of it. For *outputs*, the meaning is essentially the same except that you are indicating your perception of the potential contribution of your output (given that it is perfect) to satisfying the need(s) of its recipient(s).

Scale:	No contribution,	enter	0	in column	1
	Low contribution,	enter	1	in column	1
	Moderate contribution,	enter	2	in column	1
	High contribution,	enter	3	in column	1
	Very high contribution,	enter	4	in column	1

- Received Value (Column 2)

For *inputs*, this is your estimate of the value of the input as you usually receive it, assuming you are free to use all that you receive. Express this "received value" as a percent of the "potential contribution" indicated in column 1. For *outputs*, "received value" is your estimate of the percent of the outputs "potential contribution" normally delivered to its consumer(s).

Scale: 0 – 100% in column 2

- Utilization Value (Column 3)

For *inputs*, this is the proportion of "received value" (column 2) that you are normally able to use, considering limits imposed by time constraints, available resources for utilizing information received, etc. For *outputs*, "Utilization Value" is your perception of the proportion of "received value" ultimately used by consumers.

Scale: 0 – 100%

- Overall Benefit (Column 4)

For both *inputs* and *outputs*, this is your perception of their benefit to manpower/personnel management *in general* (considering everything you feel to be relevant).

Scale:					
	No benefit	enter	0	in column	4
	Low benefit	enter	1	in column	4
	Moderate benefit	enter	2	in column	4
	High benefit	enter	3	in column	4
	Very high benefit	enter	4	in column	4

- Other Uses (Column 5)

Indicate in this column whether to your knowledge, the given input or output is normally used for purposes other than those related to manpower/personnel planning.

Scale: *Yes* or *No*

- Feedback (Column 6)

For *inputs*, indicate whether you normally provide feedback to their sources on your perceptions of the input's value. For *outputs*, indicate whether your perceptions are based on feedback from consumer(s).

Scale:					
	No feedback	enter	0	in column	6
	Feedback sometimes	enter	1	in column	6
	Feedback most times	enter	2	in column	6
	Feedback all the time	enter	3	in column	6

Table VIII. Benefits

Code	Potential Contribution 1	Received Value 2	Utilization Value 3	Overall Benefit 4	Other Uses 5	Feedback 6
INPUTS						
A.						
B.						
C.						
D.						
E.						
F.						
G.						
OUTPUTS						
1.						
2.						
3.						
4.						
5.						
6.						

IX. Comments and Recommendations

The three questions below ask for your comments and recommendations concerning the requirement, production and flow of manpower/personnel information. We would appreciate any views that you might have about these areas. (Use back of page where necessary).

A. Are there any data or other inputs not being presently received that would significantly contribute to your effectiveness in the manpower/personnel area? If so,

(1) briefly describe the additional input(s)

_____

_____

_____

(2) state how the additional input(s) would be used

_____

_____

_____

(3) who would be the probable source of the input(s)?

_____

_____

_____

B. Similarly, if there is valuable manpower/personnel information that you could additionally produce, please indicate

(1) The nature and probable use of this information

_____

_____

_____

IX. Comments and Recommendations (Continued)

(2) Is the necessary data presently available? If so, from what source?

(3) Would significant additions to your present resources (i.e., staff, equipment, etc.) be required to produce this information?

C. Please indicate any other thoughts you have concerning possible improvements to the present flow of manpower/personnel information.

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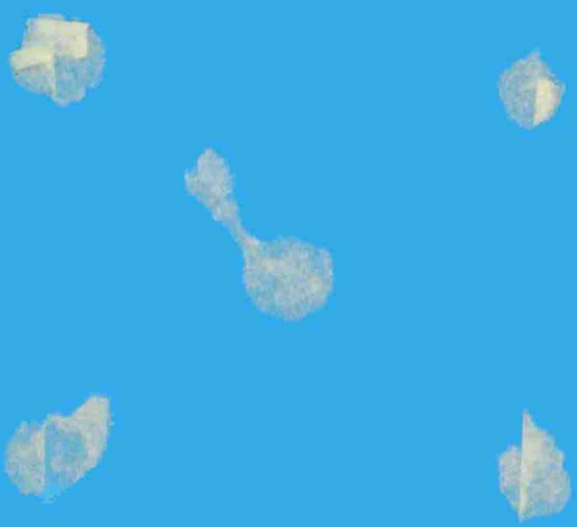

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